PUBLIC NOTICE

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AUCTION OF REGIONAL NARROWBAND PCS LICENSES SCHEDULED FOR SEPTEMBER 24, 2003

COMMENT SOUGHT ON PACKAGE BIDDING PROCEDURES, RESERVE PRICES OR MINIMUM OPENING BIDS, AND OTHER AUCTION PROCEDURES

Report No. AUC-03-51-A (Auction No. 51)

By this public notice, the Wireless Telecommunications Bureau ("Bureau") announces the auction of six regional Personal Communications Service (PCS) licenses in the 900 MHz band ("narrowband PCS") scheduled to commence on September 24, 2003 ("Auction No. 51"). These licenses were previously included as part of the inventory for Auction No. 50.[1] The one comment that the Bureau received in response to the *Auction No. 50 Comment Public Notice* stated that the regional licenses are uniquely complimentary and proposed a combinatorial (package bidding) auction.[2] The commenter noted that these regional licenses effectively constitute a nationwide license and suggested that they would be more highly valued as a combined package by prospective auction participants intending to deploy nationwide service.[3] After consideration of the issues raised by the comments, the Bureau determined that it may be appropriate to use package bidding for the regional licenses. Accordingly, the Bureau removed the six regional licenses from the Auction No. 50 inventory and announced that they would be included in Auction No. 51.[4]

The following table describes the licenses that will be included in Auction No. 51:

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[1] Narrowband PCS Spectrum Auction Scheduled for March 26, 2003; Comment Sought on Reserve Prices or Minimum Opening Bids and Other Auction Procedures, DA 02-3234, *Public Notice*, 67 Fed. Reg. 72,417 (rel. November 26, 2002) ("*Auction No. 50 Comment Public Notice*").

[2] Narrowband PCS Spectrum Auction Revised Inventory and Start Date for Auction No. 50; Notice and Filing Requirements, Minimum Opening Bids, Upfront Payments and Other Auction Procedures, DA 03-372, *Public Notice*, 68 Fed. Reg. 15,174 (rel. February 7, 2003) ("*Auction No. 50 Procedures Public Notice*").

[3] Space Data Comments in response to *Auction No. 50 Comment Public Notice* at 2-3.

[4] *Auction No. 50 Procedures Public Notice*, 68 Fed. Reg. 15,174.

Region	Channel Number	Channel Description	Frequency Bands (MHz)	Bandwidth (kHz)
Northeast	17	12.5 kHz/50 kHz paired	901.8250–901.8375, 930.70–930.75	62.5
South	16	12.5 kHz/50 kHz paired	901.8125–901.8250, 930.65–930.70	62.5
South	17	12.5 kHz/50 kHz paired	901.8250–901.8375, 930.70–930.75	62.5
Midwest	17	12.5 kHz/50 kHz paired	901.8250–901.8375, 930.70–930.75	62.5
Central	17	12.5 kHz/50 kHz paired	901.8250–901.8375, 930.70–930.75	62.5
West	17	12.5 kHz/50 kHz paired	901.8250–901.8375, 930.70–930.75	62.5

The Balanced Budget Act of 1997 requires the Commission to "ensure that, in the scheduling of any competitive bidding under this subsection, an adequate period is allowed . . . before issuance of bidding rules, to permit notice and comment on proposed auction procedures . . . ."[5] Consistent with the provisions of the Balanced Budget Act and to ensure that potential bidders have adequate time to familiarize themselves with the specific rules that will govern the day-to-day conduct of an auction, the Commission directed the Bureau, under its existing delegated authority,[6] to seek comment on a variety of auction-specific procedures prior to the start of each auction.[7] We therefore seek comment on the proposed Auction No. 51 procedures[8] as set forth in sections following the "Introduction to Package Bidding," below.

I. INTRODUCTION TO PACKAGE BIDDING

"Package bidding" refers to an auction design in which bidders may place bids on groups, or *packages*, of licenses. A bid on a package is an all-or-nothing bid for all of the licenses in that package. This is a departure from the Bureau's usual simultaneous multiple-round (SMR) design, in which bidders only have the ability to submit individual bids for each license. Like our existing SMR design, our current

[5] 47 U.S.C. § 309(j) (as amended by Section 3002(a)(E)(i), Balanced Budget Act of 1997, Pub. L. 105-33, 111 Stat. 251 (1997) ("Balanced Budget Act")).

[6] *See* Amendment of Part 1 of the Commission's Rules — Competitive Bidding Proceeding, WT Docket No. 97-82, *Order, Memorandum Opinion and Order, and Notice of Proposed Rule Making*, 12 FCC Rcd 5686, 5697, ¶ 16 (1997) ("*Part 1 Order*") (clarifying that pursuant to Section 0.131 of the Commission's rules, the Chief, Wireless Telecommunications Bureau, has delegated authority to implement all of the Commission's rules pertaining to auctions procedures).

[7] *See* Amendment of Part 1 of the Commission's Rules — Competitive Bidding Procedures, Allocation of Spectrum Below 5 GHz Transferred from Federal Government Use, 4660-4685 MHz, WT Docket No. 97-82, ET Docket No. 94-32, *Third Report and Order and Second Further Notice of Proposed Rule Making*, 13 FCC Rcd 374, 448, ¶ 124 (1998) ("*Part 1 Third Report and Order*"). The Commission directed the Bureau to seek comment on specific mechanisms related to day-to-day auction conduct including, for example, the structure of bidding rounds and stages, establishment of minimum opening bids or reserve prices, minimum acceptable bids, initial maximum eligibility for each bidder, activity requirements for each stage of the auction, activity rule waivers, criteria for determining reductions in eligibility, information regarding bid withdrawal and bid removal, stopping rules, and information relating to auction delay, suspension or cancellation. *Id.* at ¶ 125.

[8] The proposed design is essentially the same as that developed for Auction No. 31. *See generally* Auction of Licenses in the 747-762 and 777-792 MHz Bands Scheduled for June 19, 2002; Further Modification of Package Bidding Procedures and Other Procedures for Auction No. 31, *Public Notice*, 17 FCC Rcd 5140 (2002), *Erratum*, 17 FCC Rcd 7049 (2002).

implementation of package bidding uses a simultaneous multiple-round design.[9] In addition to submitting bids on packages, bidders may also submit bids on individual licenses.

A. License Complementarities

Under certain circumstances, package bidding may be desirable for bidders that wish to aggregate licenses. Bidders have aggregated licenses under our SMR auction design. However, package bidding may be appropriate when bidders have strong and divergent *complementarities* among licenses, and when package bidding rules do not introduce other undue difficulties.[10] Complementarities exist when the value of the whole is greater than the sum of the parts. In the context of spectrum auctions, complementarities could result in a bidder being willing to pay more for two licenses together than the sum of the amounts it would be willing to pay for either license individually. That is, a bidder willing to pay $1 million for a license covering Washington, D.C., or $1 million for a license covering Baltimore, Maryland, would be willing to pay more than $2 million for both licenses together.

Divergent complementarities exist when the patterns of complementarities are different for different bidders. For example, if one bidder has complementarities for a geographic aggregation and another bidder has complementarities for a bandwidth aggregation, then either of these bidders achieving its desired aggregation would prevent the other bidder from doing so. That is, if there are two licenses available in each of two markets, a bidder successfully aggregating both licenses in one market (bandwidth aggregation) precludes another bidder from aggregating one license in each market (geographic aggregation).

B. Exposure Problem

The *exposure problem* is a financial risk that occurs when a bidder, in hopes of also winning complementary items, bids more for a single object than the object alone is worth to that bidder. Package bidding allows bidders to mitigate the exposure problem by placing all-or-nothing bids on packages of licenses.[11]

The following builds upon the previous example of a bidder willing to pay $1 million for a license covering Washington, D.C., or $1 million for a license covering Baltimore, Maryland, but willing to pay more than $2 million for both licenses together. For purposes of this explanation, assume that the bidder is willing to pay $3 million for both licenses together.

In an SMR auction in which bids are submitted on individual licenses, the bidder would clearly be willing to bid $1 million for each of the Washington and Baltimore licenses, for a total of $2 million. If the auction price of one of those licenses exceeds $1 million, the bidder faces a dilemma. The bidder can stop bidding for a license when the license price exceeds what the bidder is willing to pay for that license alone, **or the bidder can keep bidding in hopes of winning both licenses**. This exposes the bidder to a financial risk. On the one hand, if the bidder wins both licenses by bidding $1 million for Washington and $1.5 million for Baltimore, it will pay a total of $2.5 million for both licenses, which is less than the $3 million it is willing to pay for both licenses together. Thus, the bidder would be satisfied with its decision to bid $1.5 million for the Baltimore license even though that license alone is only worth $1

[9] Unless otherwise specified, "SMR" will refer to SMR *without* package bidding. SMR *with* package bidding will be specified as such. Unless otherwise specified, a "package bidding auction" means an SMR auction with package bidding.

[10] *See generally* I.C, "Threshold Problem," below.

[11] In SMR auctions, the Commission generally has allowed bidders to mitigate the exposure problem by withdrawing standing high bids to the extent allowed by auction-specific procedures.

million to the bidder. On the other hand, if the bidder bids $1.5 million for the Baltimore license (again, in hopes of winning both licenses) but wins only that license and not the Washington license as well, the bidder would have to pay more for the Baltimore license than the license is worth to the bidder.

In a package bidding auction, the bidder in the above example could submit package bids to avoid such a risk. The bidder could create a package of the Washington and Baltimore licenses and submit a bid for the package. The bidder would either win the package — *i.e.*, both licenses — at the amount it bid for the package, or it would not win the package. By placing a bid on a package, the bidder would not have to worry about the possibility of only winning part of the package. That is, the bidder could bid up to $3 million for the package and thereby express what it is willing to pay not only for the licenses but also for the complementarity of the licenses.

C. Threshold Problem

Allowing package bidding potentially introduces a *threshold problem* — the difficulty that multiple bidders for the single licenses (or smaller packages) that constitute a larger package may have in outbidding a single bidder on the larger package, even though the multiple bidders may value the sum of the parts more than the single bidder values the whole. This may occur because bidders for parts of a larger package each have an incentive to hold back in the hope that a bidder for another part will increase its bid sufficiently for the bids on the pieces collectively to beat the bid on the larger package. The package bidding procedures that we propose are designed to facilitate the emergence of bids that will overcome this problem. Specifically, we propose to allow bids on licenses and packages that individually are not high enough to enter immediately into the provisionally winning set. This allowance is meant to facilitate price discovery and diminish the threshold problem. Effectively, bidders can take "baby steps" toward getting into the provisionally winning set. Additionally, under these proposed package bidding procedures, the auction will close after two consecutive rounds with no new bids. Thus, after a round with no new bids, bidders will be notified that if no new bids are placed in the subsequent round, the auction will close.

D. Other Package Bidding Highlights

Implementing package bidding requires changes in some of the procedures used in the Bureau's SMR auctions. Some of the main differences are introduced in this section in order to highlight the differences between the Bureau's proposed package bidding procedures for Auction No. 51 and the Bureau's SMR auction procedures. Later in this public notice, in the "Auction Structure" and "Bidding Procedures" sections, the Bureau seeks comment on the package bidding procedures for Auction No. 51.

1. Provisionally Winning Bids

In an SMR auction it is a simple matter to determine high bids. At the end of a bidding round, the high bids are determined based on the highest gross bid amount received for each license. A high bid from a previous round is sometimes referred to as a "standing high bid." A "standing high bid" remains the high bid until there is a higher bid on the same license at the close of a subsequent round.

In a package bidding auction, *provisionally winning bids* are similar to standing high bids. Provisionally winning bids are the set of bids that maximizes revenue at the end of a particular round. The set of provisionally winning bids cannot include overlapping bids; each license may be assigned only once. In the event of tied bids or tied sets of bids, ties are broken randomly. The set of provisionally winning bids may, of course, include package bids as well as individual license bids.

Unlike in an SMR auction, a provisionally winning bid does not necessarily remain a provisional winner until there is a higher bid on the same license or package at the close of a subsequent round. That is, a bid on a license that is a provisionally winning bid at the end of a round might not be a provisionally winning

bid at the end of a subsequent round even if no other bids are received for that license. Determining the provisionally winning bids in a package bidding auction is more complex than determining the standing high bids in an SMR auction. In a package bidding auction, whether a bid is a provisional winner depends on both the amount of the bid and the amount of revenue generated in the auction when that bid is combined with other bids submitted in the auction. With package bidding it is possible that, because of an increase in the bids submitted by one or more other bidders, a previous round's provisionally winning bid may cease to be a provisional winner in a subsequent round even though no higher bid has been placed on that license or package. In a package bidding auction, competing bids for a license or package consist of not only other bids for the same license or package, but also bids on packages that include any of the same licenses. Moreover, because of this, a bid that is not a provisionally winning bid at the end of a given round could become a provisionally winning bid at the end of a subsequent round. This is explained further in the following section.

2. All Bids Considered

Under the Bureau's proposed package bidding procedures, all bids placed in an auction are considered throughout the course of the auction. This is in contrast with the SMR procedures under which, at the conclusion of a round, only new bids placed in that round and standing high bids are considered. Bidders in a package bidding auction must therefore be mindful that even if a bid did not become a provisional winner when placed, it could become a provisionally winning bid later in the auction.

The following table portrays the six licenses available in Auction No. 51.

Channel	Region				
	West	Central	Midwest	South	Northeast
16				CN-RPC002-16 (South-16)	
17	CN-RPC005-17 (West-17)	CN-RPC004-17 (Central-17)	CN-RPC003-17 (Midwest-17)	CN-RPC002-17 (South-17)	CN-RPC001-17 (Northeast-17)

For purposes of this example, assume that bidders place the following bids in a round: $50,000 for each of the six licenses and $200,000 for the package South-16/South-17/Northeast-17 (the northeast region license and both licenses in the south region). The resulting provisionally winning bids following the round would be as follows (the individual license bids of $50,000 for each of South-16, South-17 and Northeast-17 are not provisionally winning bids and are not shown):

Channel	Region				
	West	Central	Midwest	South	Northeast
16					
17	$50,000	$50,000	$50,000	$200,000	

Total revenue = $350,000

Next, assume that a bidder places a bid of $160,000 for the package South-16/South-17 (both licenses in the south region) in the next round, and no other new bids are placed.

Channel	Region				
	West	Central	Midwest	South	Northeast
16				$160,000	
17					

Then, the provisionally winning bids following that round would be as follows:

Channel	Region				
	West	Central	Midwest	South	Northeast
16				$160,000	
17	$50,000	$50,000	$50,000		**$50,000**

Total revenue = $360,000

Note that in this example the bid of $50,000 for the northeast region license was not a provisionally winning bid after the first round but became a provisionally winning bid after the next round. The new bid of $160,000 for package of both licenses in the south region, when considered with the previous $50,000 bid for the northeast region license, was able to beat the previous $200,000 bid for the package of the northeast region license and both licenses in the south region.

Considering bids from all rounds allows more potential combinations of bids, and therefore, potentially greater flexibility for bidders to submit bids that may become part of the provisionally winning set. As in the example above, it helps ensure that bids on single licenses or small packages can combine with other bids to become winners, even when a different combination of bids has comprised the provisionally winning set for a number of rounds. Considering bids from all prior rounds also permits the bids of bidders no longer eligible to participate in the auction to become part of the provisionally winning set when that is the most economically efficient outcome. Moreover, considering all bids throughout the auction encourages sincere bidding.

3. Mutually Exclusive Rounds

As explained in the previous section, all bids placed throughout the course of the auction are considered when determining the winning bids. However, the proposed procedures restrict **how** the bids are considered. Bids placed by a bidder in one round are considered mutually exclusive of that bidder's bids placed in all other rounds. If a bidder places a bid for one license in one round and for another license in another round, one bid or the other could be a provisionally winning bid, but not both at the same time. Likewise, if a bidder places several bids in one round and several bids in another round, any or all of the bids from one round or the other could be provisionally winning bids, but not bids from both rounds at the same time.

Using the example from the previous section, assume that in the first round of the example the $50,000 bid for each of the six licenses was placed by Bidder 1 and the $200,000 bid for the package of the northeast region license and both licenses in the south region was placed by Bidder 2. In the next round of the example, the bid of $160,000 for the package of both licenses in the south region was placed by Bidder 1. Under these assumptions, the provisionally winning bids at the end of the second round could include Bidder 1's bids from one round or the other, but not both — *i.e.*, any or all of Bidder 1's $50,000 bids for each of the six licenses from the first round, or Bidder 1's bid of $160,000 for the package of both licenses in the south region from the second round. Since the choice of Bidder 1's bids in the first round achieves greater revenue, the provisionally winning bids after the second round would remain the same as after the first round:

Channel	Region				
	West	Central	Midwest	South	Northeast
16					
17	$50,000	$50,000	$50,000	$200,000	

Bidder 1 Bidder 2

Total revenue = $350,000

This treatment of bids as mutually exclusive across rounds is done on a per bidder basis. The provisionally winning bids could include Bidder 1's bids from one round and Bidder 2's bids from a different round.

This mutually exclusive treatment of bids — for each bidder, allowing its bids from only one round to become provisionally winning bids — allows bidders to mind budget constraints and to pursue backup strategies. For example, if a bidder wants the license in the west region or the license in the central region but not both, the bidder could place a bid for one of the licenses in one round and a bid for the other license in the next round. Because the bids are considered mutually exclusive, only one could become a provisionally winning bid.

4. Renewing Bids

The proposed procedures include bid renewal to provide a mechanism that bidders can use so that their bids from different rounds are not considered mutually exclusive. For example, assume a bidder places a bid for the west region license in one round. In the following round, the bidder places a bid for the central region license and renews its bid on the west region license. Then, after that round, either bid or both could become a provisionally winning bid.

This concludes the "Introduction to Package Bidding." In the following "Auction Structure" and "Bidding Procedures," sections, the Bureau seeks comment on the specific package bidding procedures for Auction No. 51.

II. AUCTION STRUCTURE

A. Simultaneous Multiple Round with Package Bidding

The Bureau proposes to award all licenses included in Auction No. 51 in a simultaneous multiple-round with package bidding (SMR-PB) auction. This methodology offers every license for bid at the same time with successive bidding rounds in which bidders may place bids. Bidders will be able to submit bids on individual licenses, as in our simultaneous multiple round auction design, but may also submit all-or-nothing bids on packages of licenses. We seek comment on this proposal.

B. Upfront Payments and Initial Maximum Eligibility

The Bureau has delegated authority and discretion to determine an appropriate upfront payment for each license being auctioned.[12] Upfront payments related to the specific spectrum subject to auction protect

[12] *Part 1 Order,* 12 FCC Rcd at 5697-98, ¶ 16; *see also Part 1 Third Report and Order*, 13 FCC Rcd at 425, ¶ 86.

against frivolous or insincere bidding and provide the Commission with a source of funds from which to collect payments owed at the close of the auction.[13] The total upfront payment does not affect the dollar amount a bidder may bid on licenses.

For Auction No. 51 we propose to calculate upfront payments on a license-by-license basis using the following formula:

$.00001 * kHz * License Area Population,[14] rounded.[15]

We seek comment on this proposal.

The amount of the upfront payment submitted by a bidder will determine the initial maximum eligibility (as measured in bidding units) for each bidder. Each license is assigned a specific number of bidding units equal to the upfront payment, on a bidding unit per dollar basis. This number does not change during the auction. A bidder's upfront payment is not attributed to specific licenses or packages. Rather, a bidder may place bids on licenses and packages as long as the total number of bidding units associated with those licenses and packages does not exceed the bidder's eligibility.[16] For a package, we propose to calculate the bidding units by adding together the bidding units of the individual licenses that make up the package. Eligibility cannot be increased during the auction. Thus, in calculating its upfront payment amount, an applicant should determine the **maximum** number of bidding units (either individually or in a package) it may wish to bid on in any single round and submit an upfront payment covering that number of bidding units. We seek comment on this proposal.

We list the proposed bidding units and upfront payments for all licenses in Attachment A.

C. Activity and Eligibility Rules

In order to ensure that the auction closes within a reasonable period of time, an activity rule provides incentives for bidders to participate throughout the auction. The activity rule requires each bidder to have active bids in each round that account for a specified fraction of the bidder's current eligibility, as measured in bidding units. A bidder that does not satisfy the activity rule will either use an activity rule waiver (if any remain) or lose bidding eligibility for the next round. Losing eligibility matters to bidders because a bidder's bidding activity cannot exceed its current eligibility.

1. Measuring Activity

In SMR auctions, a bidder's activity in a round is determined by adding the bidding units associated with licenses on which the bidder is active. A bidder is considered active on a license in the current round of an SMR auction if it is either the high bidder at the end of the previous bidding round (and did not withdraw the high bid in the current round), or if it submits a bid in the current round (and does not

[13] *See* Implementation of Section 309(j) of the Communications Act - Competitive Bidding, PP Docket No. 93-253, *Second Report and Order*, 9 FCC Rcd 2348, 2378-79, ¶¶ 171-176 (1994).

[14] All population figures are from the 2000 U.S. Census, U.S. Department of Commerce, Bureau of the Census. *See* Census 2000 Summary File 1 (SF1) and July 3, 2001, News Releases covering the U.S. Virgin Islands, Guam, the Northern Mariana Islands, and American Samoa.

[15] Results are rounded using our standard rounding procedure: results above $10,000 are rounded to the nearest $1,000; results below $10,000 but above $1,000 are rounded to the nearest $100; and results below $1,000 are rounded to the nearest $10.

[16] Bidders are permitted to bid on and create packages from only those licenses they selected on FCC Form 175.

subsequently remove the bid). In a package bidding auction, calculating activity levels in a round is not as simple because a bidder can submit bids on different packages that contain one or more of the same licenses. To illustrate this, suppose a bidder submits bids on the following packages in round *t*:

Package/Licenses		**Bidding Units**
Package A:		
South-16	(38,000 bu)	76,000 bu
South-17	(38,000 bu)	
Package B:		
Northeast-17	(34,000 bu)	108,000 bu
South-17	(38,000 bu)	
Central-17	(36,000 bu)	

For Auction No. 51, we propose to measure a bidder's *bidding activity* in a round as the maximum number of bidding units the bidder can win considering new bids placed and provisionally winning bids renewed in that round. Thus, when a bidder submits bids in a round the FCC Automated Auction System will determine the set of bids, among the bidder's new bids and renewed provisionally winning bids, that contains the most bidding units and has no overlap among the licenses. For instance, in the example above, the two bids contain four distinct licenses. The sum of the bidding units associated with these four licenses is 146,000. However, since both packages contain license South-17, this bidder cannot win both packages at the same time. Under our proposal the maximum number of bidding units that the bidder can win is the 108,000 associated with Package B, so the bidder's bidding activity is 108,000 bidding units. We seek comment on this proposal.

A bidder is also considered to be active if the bidder has provisionally winning bids from the previous round. A bidder's bids made in different rounds will be considered mutually exclusive, so the bidding units associated with provisionally winning bids must be viewed independently from the bidding units associated with current round bids. We propose to define a bidder's *eligibility activity* in a round as the greater of (i) its bidding activity in the round and (ii) the bidding units associated with the bidder's provisionally winning bids from the prior round. To illustrate how eligibility activity will be calculated in a round we continue with our example. Suppose this bidder has provisionally winning bids on the following licenses from round *t-1:*

License	**Bidding Units**
South-16	38,000 bu
South-17	38,000 bu

The number of bidding units associated with this bidder's provisionally winning bids is 76,000. Recall that the bidder's bidding activity for the round is 108,000 bidding units. The eligibility activity for this bidder in round *t* is therefore 108,000, the greater of its bidding activity (108,000 bidding units) and the bidding units associated with its bids in the provisionally winning set (76,000 bidding units).

2. Activity Requirement

For Auction No. 51, we propose that, in each round of the auction, a bidder desiring to maintain its current eligibility would be required to have eligibility activity equal to sixty percent (three-fifths) of its current eligibility. For a bidder that failed to meet the activity requirement in a given round, the Automated Auction System would reduce the bidder's eligibility for the next round to five-thirds times its

eligibility activity in the current round.[17] Thus, a bidder's eligibility in the current round is equal to either its eligibility in the previous round (bidder met the activity requirement) or five-thirds of its eligibility activity in the previous round (bidder did not meet the activity requirement), whichever is less:

$$\text{Eligibility}(t) = \text{Min}(\text{Eligibility}(t-1), 5/3 * \text{Eligibility Activity}(t-1))$$

Activity rule waivers provide an exception to this rule and are discussed in the next section, "Activity Rule Waivers and Reducing Eligibility."

In addition, we propose to retain the discretion to increase to eighty percent (four-fifths) the proportion of bidding units on which bidders must be active to retain their current eligibility. Any such change will be announced to bidders prior to the beginning of the round in which the change takes effect. We seek comment on these proposals. Commenters that believe these activity rules should be modified should explain their reasoning and comment on the desirability of an alternative approach. Commenters are advised to support their claims with analyses and suggested alternative activity rules.

3. Activity Rule Waivers and Reducing Eligibility

For Auction No. 51, we propose that each bidder be provided with five activity rule waivers that may be used at the bidder's discretion during the course of the auction as set forth below. Use of an activity rule waiver preserves the bidder's current bidding eligibility despite the bidder's eligibility activity in the current round being below the required minimum level. An activity rule waiver applies to an entire round of bidding and not to a particular license or package. Activity rule waivers are principally a mechanism for auction participants to avoid the loss of auction eligibility in the event that exigent circumstances prevent them from placing a bid in a particular round.

The Automated Auction System assumes that bidders with insufficient eligibility activity would prefer to use an activity rule waiver (if available) rather than lose bidding eligibility. Therefore, the system will automatically apply a waiver (known as an "automatic waiver") at the end of any bidding round in which a bidder's eligibility activity is below the activity requirement unless: (1) the bidder has no activity rule waivers remaining; or (2) the bidder overrides the automatic application of a waiver by reducing eligibility, thereby meeting the minimum requirements. **Note: If a bidder has no waivers remaining and does not satisfy the activity requirement, its current eligibility will be permanently reduced, possibly eliminating the bidder from further bidding in the auction.**

A bidder with insufficient eligibility activity may wish to reduce its bidding eligibility rather than use an activity rule waiver. If so, the bidder must affirmatively override the automatic waiver mechanism during the bidding period by using the "reduce eligibility" function in the bidding system. In this case, the bidder's eligibility is permanently reduced to bring the bidder into compliance with the activity rules as described in the previous section. Once eligibility has been reduced, a bidder will not be permitted to regain its lost bidding eligibility.

The activity rule waivers described above are automatic waivers. Under the Bureau's SMR auction design, bidders can submit automatic or proactive waivers. Unlike automatic waivers, proactive waivers keep the auction open absent other bidding activity. We propose not to allow bidders to submit proactive waivers in the context of package bidding for Auction No. 51. As part of the package bidding design for Auction No. 51 we are proposing a two-round simultaneous stopping rule, in which the bidding on all licenses remains open until the second consecutive round in which no new bids are placed. After the

[17] The bidder's new eligibility would be its eligibility activity in the current round multiplied by the reciprocal of the activity requirement (1/activity requirement) — in this case, (1/(3/5)), or 5/3.

second consecutive such round, bidding closes simultaneously on all licenses.[18] The two-round stopping rule affords bidders some additional time to consider their current status, and eliminates the need for bidders to use a proactive activity rule waiver to prevent the auction from closing in the current round. We seek comment on this proposal.

D. Information Relating to Auction Delay, Suspension, or Cancellation

For Auction No. 51, we propose that, by public notice or by announcement during the auction, the Bureau may delay, suspend, or cancel the auction in the event of natural disaster, technical obstacle, evidence of an auction security breach, unlawful bidding activity, administrative or weather necessity, or for any other reason that affects the fair and efficient conduct of competitive bidding.[19] In such cases, the Bureau, in its sole discretion, may elect to resume the auction starting from the beginning of the current round, resume the auction starting from some previous round, or cancel the auction in its entirety. Network interruption may cause the Bureau to delay or suspend the auction. We emphasize that exercise of this authority is solely within the discretion of the Bureau, and its use is not intended to be a substitute for situations in which bidders may wish to apply their activity rule waivers. We seek comment on this proposal.

III. BIDDING PROCEDURES

A. Round Structure

The Commission will conduct this auction over the Internet. Telephonic Bidding will also be available, and the FCC Wide Area Network will be available as well.

The initial bidding schedule will be announced in a public notice listing the qualified bidders, which is released approximately 10 days before the start of the auction. The package bidding format will consist of sequential bidding rounds, each followed by the release of round results. Details regarding the location and format of round results will also be included in a subsequent public notice.

The Bureau has discretion to change the bidding schedule in order to foster an auction pace that reasonably balances speed with the bidders' need to study round results and adjust their bidding strategies. The Bureau may increase or decrease the amount of time for the bidding rounds and review periods, or the number of rounds per day, depending upon the bidding activity level and other factors. We seek comment on this proposal.

B. Reserve Price or Minimum Opening Bid

The Balanced Budget Act calls upon the Commission to prescribe methods for establishing a reasonable reserve price or a minimum opening bid when FCC licenses are subject to auction, unless the Commission determines that a reserve price or minimum opening bid is not in the public interest.[20] Consistent with this mandate, the Commission has directed the Bureau to seek comment on the use of a minimum opening bid and/or reserve price prior to the start of each auction.[21]

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[18] The stopping rule is described more fully in III.I, "Stopping Rule," below.

[19] 47 C.F.R. § 1.2104(i).

[20] 47 U.S.C. § 309(j) (as amended by Balanced Budget Act, Section 3002(a)). The Commission's authority to establish a reserve price or minimum opening bid is set forth in 47 C.F.R. § 1.2104(c) and (d).

[21] *Part 1 Third Report and Order,* 13 FCC Rcd at 454-455, ¶ 141.

Normally, a reserve price is an absolute minimum price below which an item will not be sold in a given auction. Reserve prices can be either published or unpublished. A minimum opening bid, on the other hand, is the minimum bid price set at the beginning of the auction below which no bids are accepted. It is generally used to accelerate the competitive bidding process. Also, the auctioneer often has the discretion to lower the minimum opening bid amount later in the auction. It is also possible for the minimum opening bid and the reserve price to be the same amount.

In light of the Balanced Budget Act's requirements, the Bureau proposes to establish minimum opening bids for Auction No. 51. The Bureau believes a minimum opening bid, which has been used in other auctions, is an effective bidding tool.[22]

Specifically, for Auction No. 51, the Commission proposes the following license-by-license formula for calculating minimum opening bids:

$.00001 * kHz * License Area Population,[23] rounded.[24]

For a package, we propose to calculate the minimum opening bid by adding together the minimum opening bids of the individual licenses that make up the package. We list the proposed minimum opening bids for all licenses in Attachment A. We seek comment on this proposal.

C. Packages

The Bureau proposes that, in addition to bidding on individual licenses, bidders be permitted to create and bid on up to twelve different packages of their own choosing during the course of the auction. Bidders will not be required to identify or create their packages before the start of the auction, but may create their packages as the auction progresses.[25] A bidder may modify or delete a package it has created up until the point where it has bid on the package and the round has closed. If the bidder submits a bid on a package and subsequently removes the bid during the same round, the bidder has the option of also deleting or modifying the package. However, once a bidder bids on a package and the round closes, the package may not be modified or deleted and counts as one of the bidder's twelve allowable packages. A bid on an individual license does not count as a bid on a package; packages consist of two or more licenses. We seek comment on this proposal.

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[22] *See*, *e.g.*, Auction of 800 MHz SMR Upper 10 MHz Band, Minimum Opening Bids or Reserve Prices, *Order*, 12 FCC Rcd 16,354 (1997); Auction of the Phase II 220 MHz Service Licenses, Auction Notice and Filing Requirements for 908 Licenses Consisting of Economic Area (EA), Economic Area Grouping (EAG), and Nationwide Licenses, Scheduled for September 15, 1998, Minimum Opening Bids and Other Procedural Issues, *Public Notice*, 13 FCC Rcd 16,445 (1998).

[23] All population figures are from the 2000 U.S. Census, U.S. Department of Commerce, Bureau of the Census. *See* Census 2000 Summary File 1 (SF1) and July 3, 2001, News Releases covering the U.S. Virgin Islands, Guam, the Northern Mariana Islands, and American Samoa.

[24] Results are rounded using our standard rounding procedure: results above $10,000 are rounded to the nearest $1,000; results below $10,000 but above $1,000 are rounded to the nearest $100; and results below $1,000 are rounded to the nearest $10.

[25] Bidders are limited to bidding on, and hence creating packages from, those licenses which they selected on their FCC Form 175 and for which they have eligibility. *See generally* II.B, "Upfront Payments and Initial Maximum Eligibility," and II.C, "Activity and Eligibility Rules."

D. Winning and Provisionally Winning Bids

Winning bids in a package bidding auction are the set of "consistent" bids (non-overlapping, and for each winning bidder, only bids made or renewed in the same round) on individual licenses and packages that maximizes total revenue when the auction closes.[26] *Provisionally winning bids* are the set of consistent bids that maximizes total revenue in a particular round (they would win if the auction were to close in that round), assigning each license to either a bidder or the FCC. When determining winning and provisionally winning bids, all bids made in every round throughout the course of the auction (except for bids that are placed and subsequently removed during the same round) will be considered. In addition, each license is treated as having a bid placed by the FCC at $1000 less than the minimum opening bid. This procedure will ensure that a bid on a license or package at the minimum opening bid always beats the FCC bid.[27]

Since there can be more than one set of consistent bids that produces the maximum revenue, we propose to use a procedure that randomly selects among these tied sets when determining the provisionally winning bids. This tie breaking procedure involves two steps: (1) the assignment of a *selection number* to each bid,[28] and (2) the determination of, among all tied bid sets, the set that produces the *maximum sum of selection numbers*. We seek comment on this proposal.

A bid's *selection number* is the sum of *n* pseudo-random numbers where *n* is the number of licenses comprising the bid's package. A bid's selection number will be included in the publicly-available round results released after each round.

Once the selection numbers have been generated for each bid, the second step of the tie breaking procedure will decide the provisionally winning bids. Computer software is used to determine, among all tied bid sets, the set that produces the maximum sum of selection numbers.[29] Thus, the set of provisionally winning bids is the set of consistent bids that maximizes revenue and maximizes the sum of selection numbers. Each bid will be assigned a new selection number in every round. Consequently, if there are ties, the set of provisionally winning bids may change even after a round in which there are no new bids. The solver will not be run after the last round of the auction, so that the winning set is the same as the set of provisional winners generated after the next-to-the-last round (*i.e.*, there won't be any surprise winners).

Please note that it is possible that a provisionally winning bid might not be the highest bid on the particular license or package. This possibility is primarily due to each bidder's bids being considered

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[26] If the auction closes with any license(s) unsold, the unsold license(s) will remain held by the FCC.

[27] For example, suppose Bidder 1 bids $13,000 for License A; there are no bids for License B, which has a minimum opening bid of $10,000; and Bidder 2 bids $20,000 for Package AB. In determining the provisional winners, we will consider License B to have been bid on by the FCC at $1000 less than the minimum opening bid, i.e., $9,000. The provisional winning set will therefore consist of Bidder 1 holding License A and the FCC holding License B because the sum of their bids ($13,000+ $9,000 = $22,000) exceeds Bidder 2's bid for Package AB ($20,000).

[28] A pseudo-random number generator based on the L'Ecuyer algorithms will be used to assign a selection number to each bid. A description of the L'Ecuyer algorithms can be found in L'Ecuyer, P. (1999) "Good Parameters and Implementations for Combined Multiple Recursive Random Number Generators" *Operations Research* 47 (1), pp.159-164. A longer version of this paper and the C code for the algorithms can be found on the author's website at http://www.iro.umontreal.ca/~lecuyer/papers.html.

[29] There is a rare chance that more than one set of bids can satisfy these conditions. If such a case exists, all such sets will be generated and assigned a random number. The set with the largest associated random number will be the set of provisionally winning bids.

mutually exclusive across rounds. For example, if one bidder has placed the highest bid on each of two different licenses in two different rounds (and did not renew the earlier of the two bids), then those two bids are considered as mutually exclusive and only one of them can be a provisionally-winning bid.

E. Minimum Acceptable Bids and Bid Increments

The Bureau proposes that in each round, eligible bidders will be able to place bids on a given license or package in any of nine different amounts.[30] The Automated Auction System interface will list the nine acceptable bid amounts for each license and package. In the first round of the auction, the minimum acceptable bid for a license or package will be equal to its minimum opening bid. The Bureau proposes that in all subsequent rounds, the minimum acceptable bid for a license or package will be the greatest of: (i) the minimum opening bid; (ii) the bidder's own previous high bid on a license or package plus *x%*, where the Bureau will specify the value of *x* in each round; and (iii) the *current price estimate* of the license plus *z%*, or for a package, the sum of the current price estimates for the licenses in the package plus *z%*, where the Bureau will specify the value of *z* in each round.

Current price estimates are estimates of the prices of the individual licenses being auctioned. The estimates take into account the minimum opening bids for the licenses as well as all the bids placed in the auction and, therefore, reflect all available information that has been revealed in the auction about the relative demands for the licenses. Current price estimates for the component licenses of a package that is provisionally winning are constrained to sum to the provisionally winning bid for the package. These estimates are generated during round results following every round of the auction as part of the mathematical optimization process used by the Bureau to determine the provisionally winning bids. The precise methodology used to calculate current price estimates is described in Attachment B. Until a bid is placed on a license or on a package containing that license, by any bidder in any round, the current price estimate is the FCC bid amount.

The Bureau proposes to retain an exception to part (iii) for calculating the minimum acceptable bid for a "global" package — a package consisting of all six of the licenses available in the auction. After the first round of the auction, part (iii) of the minimum acceptable bid rule for a global package will always be the revenue generated by the provisionally winning bid set in the previous round plus *w%*. The Bureau makes this distinction in order to retain the ability to ensure that bids for the global package will continue to increase even if we employ a percentage *z* that does not guarantee that outcome.

The result of the minimum acceptable bid calculation will be rounded using our standard rounding procedure.[31] Initially, the Bureau proposes to set *x* at ten, *z* at five and *w* at five, but retains the discretion to adjust these variables during the course of the auction.

For bids higher than the minimum acceptable bid — *i.e.*, multi-increment bids — we propose to define the amount of the additional bid increments as *v%* of the minimum acceptable bid, where the minimum acceptable bid is determined as discussed above. Initially, the Bureau proposed to set *v* at ten, but proposes to retain the discretion to adjust the amount during the course of the auction. Thus, when *v* equals ten, a bidder will be able to place multi-increment bids of the minimum acceptable bid plus approximately 10%, 20%, etc. with the maximum bid being approximately equal to the minimum acceptable bid plus 80%.

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[30] Bidders must have selected the licenses on FCC Form 175 and must have sufficient eligibility to place a bid on the particular licenses or packages. *See* II.B, "Upfront Payments and Initial Maximum Eligibility," *supra*.

[31] Results above $10,000 are rounded to the nearest $1,000; results below $10,000 but above $1,000 are rounded to the nearest $100; and results below $1,000 are rounded to the nearest $10.

The Bureau retains the discretion to change minimum acceptable bids, and to do so on a license-by-license and package-by-package basis, if circumstances so dictate. The Bureau will do so by announcement in the Automated Auction System.[32] We seek comment on these proposals.

F. Last and Best Bids

We propose to allow bidders that wish to drop out of the auction or that believe they are about to lose their bidding eligibility to have an opportunity before they drop out to place up to two mutually exclusive sets of "last and best" bids on any licenses or packages for which they remain eligible. This is a limited exception to minimum acceptable bids and to click-box bidding. Such bids may be of any amount (in thousand dollar increments) between the bidder's previous high bid on the license or package and the amount of the highest acceptable bid for the license or package in the current round (the eighth increment above the minimum acceptable bid).[33] If a bidder chooses this option, it will not be permitted to make any further bids during the auction. We seek comment on this proposal.

G. Renewed Bids

Without regard to the minimum acceptable bid requirement, we propose to allow a bidder to "renew" in the current round the highest previous bid it made on any license or package; that is, it may resubmit the bid without increasing the amount bid. No eligibility activity or bidding activity is conferred for renewing a non-provisionally winning bid. Renewed provisionally winning bids confer bidding activity (non-renewed provisionally winning bids count toward eligibility activity). Renewed bids will be treated as being made in the current round.

Renewals provide bidders a means to ensure that bids from previous rounds are considered *in addition to* the bids placed in the current round. Otherwise, bids made in different rounds are treated as mutually exclusive, so that the bidder may win some or all of the bids from the current round, or a previous round, but not both. We seek comment on this proposal.

H. Information Regarding Bid Removal and Bid Withdrawal

For Auction No. 51, the Bureau proposes the following bid removal procedures. Before the close of a bidding period, a bidder has the option of removing any bid placed in that round. By removing selected bids in the bidding system, a bidder may effectively "unsubmit" any bid placed within that round. A bidder removing a bid placed in the same round is not subject to a withdrawal payment. Once a round closes, a bidder may no longer remove a bid.

The Bureau proposes for Auction No. 51 that bidders not be permitted, in any round, to withdraw bids made in previous rounds. With the implementation of package bidding, bidders should not face exposure risks as they might in a simultaneous multiple round auction design. Bid withdrawal was designed to allow bidders to back out of failed aggregations — to avoid winning some licenses that are worth little to

[32] As described further in the "Renewed Bids" and "Last and Best Bids" sections, there are two exceptions to the minimum acceptable bid requirement. First, bidders who choose to place no further bids in the auction may place "last and best bids" at any amount between the bidder's previous high bid — or, if the bidder has not placed a bid on the license or package, the minimum opening bid — and the eighth increment above the minimum acceptable bid. Second, at any time bidders may "renew" their highest previous bid on a license or package without increasing the bid: however, a bidder is not conferred activity of any kind for renewing a non-provisionally winning bid. Because bids in each round are considered mutually exclusive, renewing a provisionally winning bid does not double count that bid towards a bidder's total eligibility activity credit.

[33] If the bidder has never placed a bid on the license or package, the lower bound on the last and best bid amount will be equal to the minimum opening bid.

them without the others they need to implement their business plan. Therefore, to the extent that bids are allowed on all packages of licenses with significant complementarities, the use of withdrawals to mitigate such risk is no longer necessary. We seek comment on this proposal.

I. Stopping Rule

The Bureau has discretion "to establish stopping rules before or during multiple round auctions in order to terminate the auction within a reasonable time."[34] For Auction No. 51 the Bureau proposes to employ a two-round simultaneous stopping rule. A two-round simultaneous stopping rule means that all licenses remain open until two consecutive rounds have occurred in which no new bids are received. After the second consecutive such round, bidding closes simultaneously on all licenses. Thus, unless circumstances dictate otherwise, bidding would remain open on all licenses until bidding stops on every license. Renewed bids are not considered new bids for purposes of the stopping rule; in other words, a round in which the only bids that are placed are renewed bids is considered a round with no new bids for purposes of the stopping rule. Last and best bids are considered new bids for purposes of the stopping rule. We seek comment on this proposal.

The Bureau proposes to reserve the right to declare that the auction will end after a specified number of additional rounds ("special stopping rule"). The Bureau proposes to exercise this option only in certain circumstances, such as, for example, where the auction is proceeding very slowly, there is minimal overall bidding activity, or it appears likely that the auction will not close within a reasonable period of time. Before exercising this option, the Bureau is likely to attempt to increase the pace of the auction by, for example, increasing the number of bidding rounds per day, and/or increasing the minimum acceptable bids. We seek comment on these proposals.

IV. CONCLUSION

Comments are due on or before April 17, 2003, and reply comments are due on or before April 24, 2003. Because of the disruption of regular mail and other deliveries in Washington, DC, the Bureau requires that all comments and reply comments be filed electronically. Comments and reply comments must be sent by electronic mail to the following address: auction51@fcc.gov.[35] The electronic mail containing the comments or reply comments must include a subject or caption referring to Auction No. 51 Comments. The Bureaus request that parties format any attachments to electronic mail as Adobe® Acrobat® (pdf) or Microsoft® Word documents. Copies of comments and reply comments will be available for public inspection during regular business hours in the FCC Public Reference Room, Room CY-A257, 445 12th Street, SW, Washington, DC 20554. Copies of comments and reply comments will also be available from the Commission's copy contractor: Qualex International, 445 12th Street, SW, Room CY-B402, Washington, DC 20554; phone (202) 863-2893; fax (202) 863-2898; e-mail qualexint@aol.com.

In addition, the Bureaus request that commenters fax a courtesy copy of their comments and reply comments to the attention of Kathryn Garland at (717) 338-2850.

This proceeding has been designated as a "permit-but-disclose" proceeding in accordance with the Commission's *ex parte* rules.[36] Persons making oral *ex parte* presentations are reminded that memoranda

[34] 47 C.F.R. § 1.2104(e).

[35] Comments and reply comments in response to this Public Notice may not be filed using the Commission's Electronic Comment Filing System, which is used for the Commission's docketed rule making proceedings.

[36] 47 C.F.R. §§ 1.1200(a), 1.1206.

summarizing the presentations must contain summaries of the substance of the presentations and not merely a listing of the subjects discussed. More than a one or two sentence description of the views and arguments presented is generally required.[37] Other rules pertaining to oral and written *ex parte* presentations in permit-but-disclose proceedings are set forth in Section 1.1206(b) of the Commission's rules.[38]

For further information concerning this proceeding, contact:

Auctions and Industry Analysis Division, WTB

For legal questions:	Christopher Shields at (202) 418-0660
For general auction questions:	Lisa Stover at (717) 338-2888
For questions about package bidding:	Martha Stancill at (202) 418-0660 Craig Bomberger at (202) 418-0660

Commercial Wireless Division, WTB

For service rule questions:	Amal Abdallah at (202) 418-7307 Evan Baranoff at (202) 418-7142 JoAnn Epps at (202) 418-0620 Dwain Livingston at (202) 418-0620

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[37] 47 C.F.R. § 1.1206(b).

[38] *Id*.

ATTACHMENT A

Placeholder for Attachment A

ATTACHMENT B

Using the Smoothed Anchoring Method to Obtain Current Price Estimates

This appendix describes the method by which bid information on packages and licenses is used to approximate a "price" associated with each license at the close of every round. These "current price estimates," as they are called, are then used in the next round when calculating part (iii) of the proposed minimum acceptable bid formula.[39] Specifically, for a license, this value is the current price estimate of the license plus z%. For a package, the value is the sum of the current price estimates of the licenses that make up the package plus z% of the sum.

The current price estimates of the licenses are based on the concept that every linear optimization problem has a dual problem that provides pricing information. We begin by discussing a simplified representation of the FCC winner determination problem and then discuss its linear programming relaxation before explaining the dual problem of interest. The winner determination problem is shown in (P1):

$$\text{(P1):} \quad \begin{aligned} &\max \quad \sum_{j \in B^t} b_j x_j \\ &s.t. \quad \sum_{j \in B^t} a_{ij} x_j = 1, \quad \text{for all } i \in L \qquad (1) \\ &\qquad x_j \in \{0,1\}, \qquad \text{for all } j \in B^t \end{aligned}$$

where B^t is the set of considered bids in round *t,*
b_j is the bid amount of bid *j,*
L is the set of licenses being auctioned,

$$a_{ij} = \left\{ \begin{matrix} 1 & ,\textit{if license } i \textit{ is in bid } j \\ 0 & ,\textit{otherwise} \end{matrix} \right\} \text{ and,}$$

$$x_j = \left\{ \begin{matrix} 1 & ,\textit{if bid } j \textit{ is in the winning set} \\ 0 & ,\textit{otherwise} \end{matrix} \right\}$$

In this formulation, x_j is an indicator variable that equals one if bid *j* is in the provisionally winning set and zero otherwise. Thus, the sum of the bid amounts of all provisionally winning bids produces the maximum obtainable revenue for round *t*. Constraints (1) ensure that each license is awarded exactly once. The constraints that ensure that a bidder's bids between rounds are mutually exclusive are not represented in (P1) since they will be ignored in the linear representation of the problem.[40]

[39] In addition to the part (iii) formula derived here, the minimum acceptable bid also considers part (i) and (ii) amounts, where (i) is the minimum opening bid and (ii) is the bidder's own previous high bid plus x%, where x is specified by the Bureau. The minimum acceptable bid is the *greatest* of the three amounts.

[40] These constraints will be ignored in the linear program representation since they are rarely binding in the relaxation of the integer-programming problem and because adding such constraints to the dual problem creates "degeneracy" in the solution thereby causing multiple alternative solutions.

The linear program of (P1) relaxes the restriction on the variables x_j, for all $j \in B^t$, allowing these variables to take on any value between zero and one. The linear programming representation of (P1) is shown in (P2):

$$\text{(P2):} \quad \begin{aligned} \max \quad & \sum_{j \in B^t} b_j x_j \\ s.t. \quad & \sum_{j \in B^t} a_{ij} x_j = 1, \qquad \text{for all} \quad i \in L \\ & x_j \geq 0, \qquad \text{for all} \quad j \in B^t \end{aligned}$$

The dual formulation of (P2) can be used to identify a price, π_i, for each license i, and is shown in the following linear program (P3):

$$\text{(P3):} \quad \begin{aligned} \min \quad & \sum_{i \in L} \pi_i \\ s.t. \quad & \sum_{i \in L} a_{ji} \pi_i \geq b_j, \ \text{for all} \ j \in B^t \setminus F \qquad (2) \\ & \pi_i \geq b_j, \qquad \text{for all} \ j \in F \\ & \qquad \text{and } i \text{ is the license index associated with bid } j \qquad (3) \end{aligned}$$

where $F \subset B^t$ is the set of FCC bids on each license[41] and,

$$a_{ji} = \left\{ \begin{matrix} 1 \ , \textit{if bid } j \textit{ contains license } i \\ 0 \ , \textit{otherwise} \end{matrix} \right\}.$$

The optimal value of each variable, π_i, in (P3) corresponds to a dual price[42] – often called a "shadow price" – for each constraint, i.e., each license, in (P2). The dual price of each license measures the monetary cost of not awarding the license to whom it has been provisionally assigned under the solution to (P2). Thus, this monetary cost has a clear and natural use in estimating the current price of a license given the bids considered in the current round.

Constraints (2) in (P3) ensure that the dual price of a license must be at least as large as the greatest bid made on that license. For a package, these constraints ensure that the sum of the dual prices of the licenses that make up a particular package must be at least as large as the greatest bid made on that package. Constraints (3) in (P3) ensure that if a license has not been bid on, the dual price of that license is at least as large as the FCC bid amount.

Ideally, the solution to (P2) is identical to the solution of (P1). When this occurs, the sum of the dual prices of the licenses comprising any provisionally winning bid equals the winning bid amount. However,

[41] The bid amount for a FCC bid is some small amount less than the minimum-opening bid for that license. *See* Auction Of Licenses in the 747-762 and 777-792 MHz Bands Scheduled for March 6, 2001; Modifications to the Calculation for Determining Minimum Acceptable Bids and the Provisions Concerning "Last and Best Bids" and Other Procedural Issues, DA 01-12, *Public Notice*, 16 FCC Rcd 217 (2001) (Section III discusses the reasons for this approach).

[42] We note that for non-linear problems, these dual prices are also known as *Lagrange multipliers.*

(P2) is only an approximation to the integer problem[43] and often *overestimates* the maximum revenue of (P1). When this occurs, the sum of the dual prices of the licenses in at least one provisionally winning bid will be greater than the respective bid amount. Thus, using the dual prices of (P3) can result in minimum acceptable bid amounts that are too high.

We propose to resolve this issue by using *pseudo-dual prices,*[44] rather than the dual prices of (P3). These pseudo-dual prices are obtained by forcing the sum of the dual prices of the licenses comprising a provisionally winning bid to equal its respective bid amount. For example, suppose there are two bids in the provisionally winning set in round *t*: a bid on license A for $10 and a bid on package BC for $25. The pseudo-dual price of A would exactly equal $10 and the sum of the pseudo-dual prices of B and C would exactly equal $25. These restrictions ensure that the sum of the pseudo-dual prices equals the maximum revenue for the round (e.g. $35) and that minimum acceptable bid amounts reflect the bid amounts of bids in the provisionally winning set.

Pseudo-dual prices for each license i, denoted π_i, satisfy the following constraints:

$$\sum_{i \in L} a_{ji}\pi_i + \delta_j \geq b_j, \text{ for all } j \in B^t \setminus (W^t \cup F) \quad (4)$$

$$\sum_{i \in L} a_{ji}\pi_i = b_j, \quad \text{for all } j \in W^t \quad (5)$$

$$\pi_i \geq b_j, \quad \text{for all } j \in F \setminus (W^t \cap F) \text{ and } i \text{ is the license index associated with bid } j \quad (6)$$

$$\delta_j \geq 0, \quad \text{for all } j \in B^t \setminus (W^t \cup F) \quad (7)$$

where $W^t \subset B^t$ is the provisionally winning bid set in round t and,
δ_j is a slack variable that represents the difference between the bid amount of non-winning bid j and the sum of pseudo-dual prices of the licenses contained in non-winning bid j

Constraints (5) ensure that for each provisionally winning bid, the sum of the dual prices of the licenses comprising that bid equal its respective bid amount. This new restriction requires that we ease restriction (2) in (P3) for non-winning bids in order to ensure that a feasible solution exists. Constraints (4) provide this needed slack. Constraints (6) are equivalent to constraints (3) in (P3) and constraints (7) force the slack variables to be non-negative.

Satisfying constraints (5) implies that the sum of the pseudo-dual prices always yields the maximum revenue for the round. There are likely to be many sets of pseudo-dual prices that satisfy this constraint set. For instance, in the example provided earlier, the pseudo-dual prices of B and C might be any two numbers that together sum to $25.

[43] When the problem is a convex optimization problem, the primal and dual problems yield the same objective function values. This is called strong-duality. These conditions do not hold for integer programming problems, often resulting in a gap between the linear programming and integer programming solution values.

[44] In our research we found this term first applied to auction pricing in the paper by Rassenti, Smith and Bulfin (1982), "A Combinatorial Auction Mechanism for Airport Slot Allocation," *Bell Journal of Economics*, vol. 13, pp. 402-417.

By keeping constraints (4)-(7), we have the flexibility to choose an objective function that will help in selecting among multiple solutions while still ensuring that the sum of the pseudo-dual prices yields the maximum revenue of the round. We would like an objective function that minimizes the values of the slack variables δ_j, for all $j \in B^t \setminus (W^t \cup F)$ in order to obtain pseudo-dual prices that are close to the dual prices of (P3). We have tested a number of alternative objective functions:

1. Minimization of the maximum δ_j for all $j \in B^t \setminus (W^t \cup F)$ followed by maximization of the minimum π_i for all i in license set L, in an iterative manner. (DeMartini, Kwasnica, Ledyard and Porter, 1999)
2. Minimization of the sum of the squares of δ_j for all $j \in B^t \setminus (W^t \cup F)$. (also DeMartini, Kwasnica, Ledyard and Porter, 1999)
3. Minimization of the sum of the δ_j for all $j \in B^t \setminus (W^t \cup F)$ using a "centering" algorithm[45] to solve, essentially finding an average among all sets of optimal pseudo-dual prices.

In testing the above alternatives, we frequently observed instances where the pseudo-dual price of a license significantly changed from round to round. We acknowledge that prices of licenses should be allowed to reflect real changes, both increases and decreases, in the way bidders value the licenses over time. However, we believe that large oscillations in minimum acceptable bid amounts for the same bid that are due to irrelevant factors such as multiple optimal solutions, can be confusing to bidders. We have therefore chosen a method that attempts to balance minimizing the slack variables and reducing the fluctuations in pseudo-dual prices from round to round. This method requires solving two optimization problems, the first of which is alternative 3 above, which we present as (P4):

$$\Omega^* = \min \sum_{j \in B^t \setminus (W^t \cup F)} \delta_j$$

$$s.t. \quad \sum_{i \in L} a_{ji}\pi_i + \delta_j \geq b_j, \text{ for all } j \in B^t \setminus (W^t \cup F)$$

(P4):
$$\sum_{i \in L} a_{ji}\pi_i = b_j, \qquad \text{for all } j \in W^t$$

$$\pi_i \geq b_j, \qquad \text{for all } j \in F \setminus (W^t \cap F)$$

$$\text{and } i \text{ is the license index associated with bid } j$$

$$\delta_j \geq 0, \qquad \text{for all } j \in B^t \setminus (W^t \cup F)$$

Since multiple optimal solutions can exist to (P4) we solve a second optimization problem that chooses a solution in a way that reduces the magnitude of price fluctuations between rounds. Specifically, we use an objective function that applies the concepts of exponential smoothing[46] to choose among alternative pseudo-dual prices with the additional constraint on the problem that the sum of the slack variables equals Ω^* (the optimal value of (P4)). This objective function minimizes the sum of the squared deviations of

[45] The centering algorithm used in this testing was the barrier method available in CPLEX, a commercial optimization package.

[46] Exponential smoothing often is used in determining minimum acceptable bids in FCC auctions. *See, e.g.,* Auction of Licenses in the 698-746 MHz Band Scheduled for June 19, 2002; Notice and Filing Requirements, Minimum Opening Bids, Upfront Payments and Other Auction Procedures, DA 02-563, *Public Notice*, 17 FCC Rcd 4935, 4971-4972, 5003-5005 (rel. March 20, 2002) ("*Auction No. 44 Procedures Public Notice*").

the resulting pseudo-dual prices in round *t,* from their respective smoothed prices in round *t-1*.[47] At the start of the auction, we use the minimum opening bid prices as the prior smoothed prices. Since these opening prices are based on bandwidth and population, the pricing algorithm begins with *a priori* information about the differences among licenses.

Let π_i^t be the pseudo-dual price of license *i* in round *t.* The smoothed price for license *i* in round *t* is calculated using the following exponential smoothing formula:

$$p_i^t = \alpha\pi_i^t + (1-\alpha)p_i^{t-1}$$

where p_i^{t-1} is the smoothed price in round *t*-1,

$0 \le \alpha \le 1$, and

p_i^0 = the minimum opening bid amount for license *i.*

Consistent with prior practice of the Commission, a weighting factor of $\alpha = 0.5$ has been chosen but can change, as the Commission requires.

The following quadratic program (QP) will find the pseudo-dual price, π_i^t, for each license *i* in round *t* that minimizes the sum of the squared deviations from the respective smoothed prices in round *t-1* while ensuring that the pseudo-dual prices sum up to the provisionally winning bid amounts and that the sum of the slack variables is minimized.

$$\begin{aligned}
&\min \quad \sum_{i\in L}(\pi_i^t - p_i^{t-1})^2 \\
&s.t \quad \sum_{i\in L} a_{ji}\pi_i^t + \delta_j \ge b_j, \quad \text{for all } j \in B^t \setminus (W^t \cup F) \\
&\qquad \sum_{i\in L} a_{ji}\pi_i^t = b_j, \qquad \text{for all } j \in W^t \\
\text{(QP):} \quad &\sum_{j\in B^t\setminus(W^t\cup F)} \delta_j = \Omega^* \\
&\pi_i^t \ge b_j, \qquad \text{for all } j \in F \setminus (W^t \cap F) \\
&\qquad\qquad \text{and } i \text{ is the license index associated with bid } j \\
&\delta_j \ge 0, \qquad \text{for all } j \in B^t \setminus (W^t \cup F)
\end{aligned}$$

where p_i^{t-1} is known and treated as a constant within the optimization.[48]

Among alternative prices that satisfy all constraints, the objective function of this optimization problem chooses one that forces the pseudo-dual prices to be as close as possible to the previous round's smoothed

[47] This objective function is a convex, quadratic function. This quadratic optimization problem is solved using the barrier method.

[48] Once the pseudo-dual prices, π_i^t, have been determined, the smoothed prices, p_i^t, can be calculated and used for solving (QP) in round *t+1*.

price. Thus, we call this the *Smoothed Anchoring Method* since we "anchor" on the smoothed prices when solving for the pseudo-dual prices. We define the "current price estimate" for license *i* in round *t* as the pseudo-dual price, π_i^t, obtained by solving (QP).

The minimum acceptable bid amount for a license in round *t+1* under part (iii) will be the current price estimate of the license, as calculated above, plus z%. For a package, the value will be the sum of the current price estimates of the licenses that make up the package plus z% of the sum. This part (iii) amount is then compared to the amounts of parts (i) and (ii), and the greatest is the minimum acceptable bid for the next round.